DE GRUYTER OPEN
DOI: 10.2478/aslh-2013-0004 *Acta Silv. Lign. Hung., Vol. 9 (2013) 43–56*

The Effect of Herb Layer on Nocturnal Macrolepidoptera (Lepidoptera: Macroheterocera) Communities

Bálint HORVÁTH[a*] – Viktória TÓTH[a] – Gyula KOVÁCS[b]

[a] Institute of Silviculture and Forest Protection, University of West Hungary, Sopron, Hungary
[b] Institute of Wildlife Management and Vertebrate Zoology, University of West Hungary, Sopron, Hungary

Abstract – Vegetation beneath the canopy might be an important factor for macromoth community composition in forest ecosystems, strongly determined by forest management practices. Herein, we compared nocturnal macrolepidoptera communities and herb layers in young and old sessile oak (*Quercus petraea*) dominated forest stands in the Sopron Mountains (Western Hungary). The investigation of Lepidoptera species was performed 15 times from the end of March to the end of October in 2011. Portable light traps were used, and a total of 257 species and 5503 individuals were identified. The Geometridae family was the most abundant, followed by Noctuidae and Notodontidae. To investigate vascular plant species in the herb layer, circular plots with a 10-m radius around the moth traps were used. In each plot, we estimated the abundance of plant species in 20 sub-plots with a 1-m radius from May to July of 2011. The abundance of macromoth species was higher in the old forest stand, which might be influenced by the trees' higher foliar biomass. However, the mean abundance of herbs was lower in the old forest. Diversity of both the herb layer and the moth community were significantly higher in the young forest. However we found higher species richness of moths in the old forest. For additional analyses, moths feeding on plants in the herb layer were selected, but neither the difference in species number, neither mean abundance between the young and old forest were significant. Our results suggest that the herb layer is not a key factor for macrolepidoptera communities in Hungarian sessile oak forest stands.

Sopron Mountains / diversity / sessile oak (*Quercus petraea*) / Lepidoptera / vascular plants

Kivonat – Éjszakai nagylepke közösségek (Lepidoptera: Macroheterocera) és a gyepszint diverzitásának kapcsolata. Az erdei ökoszisztémák éjszakai lepkeközösségének összetételét a lombkoronaszint alatti növényzet erősen befolyásolja, amely közvetett úton az erdészeti kezelések következménye. A szerzők jelen dolgozatban egy idős és egy fiatal, kocsánytalan tölgy (*Quercus petraea*) által dominált erdőállomány gyepszintjének és éjszakai nagylepke közösségének kapcsolatát vizsgálták. Összesen 15 alkalommal történt éjszakai lepke mintavétel, 2011 márciusától novemberéig, hordozható fénycsapdák alkalmazásával. A vizsgálat során 257 nagylepke faj 5503 egyedét figyeltük meg. Fajokban leggazdagabb az araszoló lepkék családja (*Geometridae*) volt, ezt követték a bagolylepkék (*Noctuidae*) és a púposszövők (*Notodontidae*) családja. A gyepszint növényzetét 20 darab 1 méter sugarú mintavételi körben vizsgáltuk, a csapdák 10 méteres körzetében. A mintavételezést 2011 májusától júliusáig végeztük. Az éjszakai nagylepkék egyedszáma az idős erdőben volt magasabb, ami az idősebb fák nagyobb biomassza produktumával magyarázható.

* Corresponding author: hbalint@emk.nyme.hu; H–9400 SOPRON, Bajcsy-Zs. u. 4.

Ugyanakkor a gyepszint növényfajainak abundanciája alacsonyabb volt az idős erdőben. A gyepszint és az éjszakai nagylepkék diverzitási indexei szignifikánsan magasabb értéket mutattak a fiatal erdőben, az éjszakai nagylepkék fajszámát az idős erdőben találtuk magasabbnak. További elemzéseket végeztünk a gyepszintben (illetve a gyepszintben is) fejlődő lepkefajokon, mint modellcsoporton, de sem a fajszámban, sem a mintánkénti átlagos egyedszámban nem volt szignifikáns különbség a mintaterületek között. Eredményeink alapján arra következtethetünk, hogy a gyepszint önmagában nem meghatározó tényezője az éjszakai nagylepke közösségeknek, a vizsgáltakhoz hasonló hazai kocsánytalan tölgyes erdőkben.

Soproni-hegység / diverzitás / kocsánytalan tölgy (*Quercus petraea*) / Lepidoptera / lágyszárú edényes növények

1 INTRODUCTION

A question posed by many community ecologists is which factors influence biodiversity. The answer is multiple factors, but specialists have agreed that plants have an important role. One of the key components in maintaining the biodiversity of temperate forests is the vegetation (Thomas – Packham 2007, Schowalter 2011). The largest mass of herbivores is represented by insects, an abundant and diverse group. In addition, numerous insects have adapted to special environmental conditions, and thus are suitable as indicators of biodiversity (New 2009, Park et al. 2009). Numerous insect species respond rapidly to changes in their habitat (Wood – Storer 2003). For that reason, the structure of the forest vegetation is important for insect herbivores, which closely depend on plants for their development and survival (Summerville – Crist 2003). The density and species richness of forest insects are strongly determined by forest management – especially for specialist insects, which feed on a limited number of plant species (Thomas – Packham 2007). Forests in Hungary are often under pressure from intensive timber harvesting, which possibly have a significant influence on the vegetation and animals.

Lepidoptera species are among the most studied insects in the world, and they have been widely used in ecological studies (Kitching et al. 2000, Summerville – Crist 2003, Summerville et al. 2004, Park et al. 2009). Although butterflies are more often investigated (e.g. Jeanneret et al. 2003, Tudor et al. 2004, Benes et al. 2006, Cleary – Genner 2006), however moth species play a more significant role in forest ecosystems because the species richness of butterflies is much lower in forests (Scoble 1992, Schmitt 2003).

The effect of herb layer on Lepidoptera species in Hungarian forests is less studied. In this study, we investigated the relationship between the herb layer and macromoth community in two Hungarian forest stands. We supposed there was an influence of vascular plants on macromoths.

2 MATERIALS AND METHODS

2.1 Study area

The investigation was conducted in an area of approximately 5000 hectares in the Sopron Mountains in the Lower Austroalpides. Approximately 90% of the area is forested (Dövényi 2010). The intensive use of the forests near Sopron has started in the 12th or 13th century. After 1850, many indigenous forests were replaced by pine cultures, and the proportion of the deciduous forests continually decreased until the 1980's. This is the primary reason why the composition of several forests differs from the natural stands in the Sopron Mountains (Tamás 1955, Szmorad 2011).

One of the most common forest types in the Sopron Mountains are sessile oak-hornbeam woodlands. These forests are dominated by *Quercus petraea* agg. and *Carpinus betulus*. In the tree layer, *Tilia cordata*, *Castanea sativa*, *Fagus sylvatica* and *Cerasus avium* are the most common additional species, although coniferous tree species (e.g., *Larix decidua, Pinus sylvetris,* and *Picea abies*) also occur. The shrub layer is usually not dense, comprising of young tree species (*Carpinus betulus, Tilia cordata* and *Castanea sativa*) and some mesic shrub species (*Cornus sanguinea* and *Corylus avellana*). The herb layer is strongly varied according to ecological conditions, but both general and mesic forest species elements compose the undergrowth (Szmorad 2011, Bölöni et al. 2008).

Conifer forests were avoided in this study, as we focused only on two indigenous, sessile oak dominated forest stands: young (23 years old) and old (84 years old).

2.2 Moth sampling

Within each forest stand, nocturnal Lepidoptera species were sampled 15 times from the end of March to the end of October in 2011, every two weeks, using portable light traps (using a 3 piece UV LED, peak wavelength 400–410 nm, operated by a 4.5 V battery). Although light traps operated with various light sources have different levels of attraction for Lepidoptera families (Nowinszky – Ekk 1996, Puskás – Nowinszky 2011), UV light traps are widely used for sampling moth communities (Summerville – Crist 2003). This method is used for collecting phototactic species. Two traps were used in each forest stand, positioned on the ground and with 50 m apart. Samples in the two sites were taken simultaneously. Light trapping was regularly performed during the night (from sunset to sunrise) and ceased during heavy rain. Attracted moths were sacrificed using ethyl acetate as a killing agent inside the traps.

The collected Lepidoptera specimens were frozen until the identification. Most of the individuals were identified by macro-morphological features. The exceptions were *Eupithecia* sp., *Mesapamea* sp. and damaged specimens, which were identified by genitalia investigation. The abdomens of specimen were macerated in 10% cold KOH overnight, than hot for a few minutes before the identification.

2.3 Vascular plant sampling

Vascular plant species in the herb layer were screened from May to July in 2011, using Simon’s (2000) nomenclature. Vegetation was semi-systematically sampled. Circular plots with a 10-m radius around the moth traps were used. In each plot, we selected 20 sub-plots with a 1-m radius each. We used 4 sub-plots among 4-m radius circle and 8–8 sub-plots among 6-m and 10-m radius circle. Presence and absence data were recorded within the sub-plots. To estimate the abundances of the vascular plants, we calculated the frequency, which is a generally used method to survey herb layer (Morrison et al. 1995).

2.4 Data analysis

The community and ecological parameters of the Lepidoptera and vascular plant communities were examined and compared in the sampling sites using the Past package (Paleontological Statistics Software 2.17) (Hammer et al. 2001).

The dominance of the most abundant Lepidoptera families was compared using the χ^2-test. The measure of diversity was determined by the Shannon index (Shannon – Weaver 1949), Simpson index (Simpson 1949) and Pielou’s equitability formula (Pielou 1966). We used the bootstrap method to compare the diversities (Efron 1979).

The general trends of the Lepidoptera dominance structure and abundance for each sampling site were displayed using a rank-abundance plot. A log-series model (Fisher et al. 1943) (with two parameters α and x) was used. The fitting algorithm was from Krebs (1989), Sn=αxn/n, for the number of species (Sn) with n individuals; the fitting test was calculated using the χ^2-test.

To compare the mean of the Lepidoptera and vascular plant abundances, the t-test was used.

3 RESULTS

During our study, a total of 257 Lepidoptera species and 5503 individuals were identified from 9 families, using Varga's (2010) nomenclature (1. appendix). The most abundant was the Geometridae family, followed by Noctuidae and Notodontidae. The proportion of these three families was significantly different (χ^2=6.68, p=0.04) between the old and young forests (*Figure 1*). However, there was no significant difference in the comparison of the mean number of Lepidoptera individuals in each family (*Figure 2*).

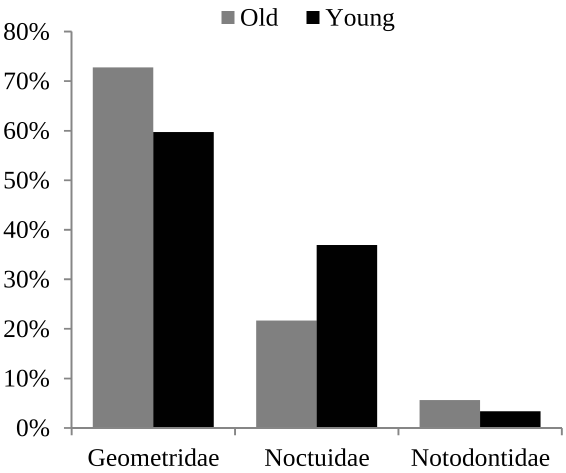

Figure 1. The proportion of the most abundant Lepidoptera families in the old and young forests

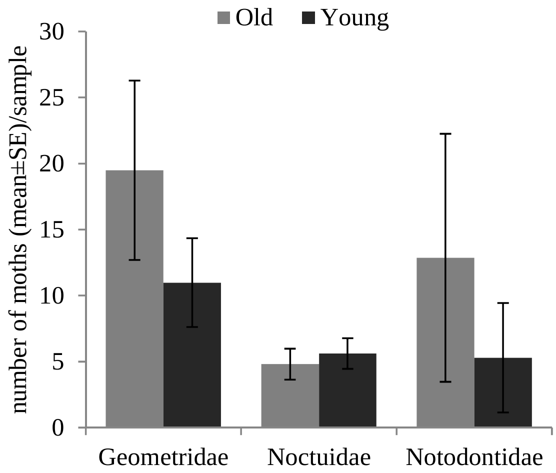

Figure 2. Average number of specimen per most abundant Lepidoptera families per study sites

Species richness of Lepidoptera was higher in the old forest, while species richness of the vascular plants was higher in the young forest. The abundance of Lepidoptera species was also higher in the old forest stand (old forest: 3270 specimens; young forest: 2233 specimens). The measure of the diversity indices (Shannon, Simpson and equitability) was higher in the young forest for both the Lepidoptera and vascular plant communities. The compared diversities showed significant differences between the sampling sites (*Table 1*).

Table 1. Diversity indices of nocturnal Lepidoptera and vascular plant communities in the old and young forests

	Moth			Plant		
	Old	Young	Bootstrap p	Old	Young	Bootstrap p
Species richness	203	192	–	28	32	–
Shannon index	3,668	3,994	0,001	0,908	0,942	0,002
Simpson index	0,929	0,957	0,001	2,748	3,056	0,015
Equitability	0,690	0,760	0,001	0,825	0,882	0,02

There were some differences also in proportions of dominant and rare Lepidoptera species between the sampling sites (old forest: α=47.9, x=0.986, χ^2=2123, p<0.05; young forest: α=50.32, x=0.978, χ^2=566.8, p<0.05). Most species were rare, as indicated by the step initial gradients in the rank abundance plot (*Figure 3*).

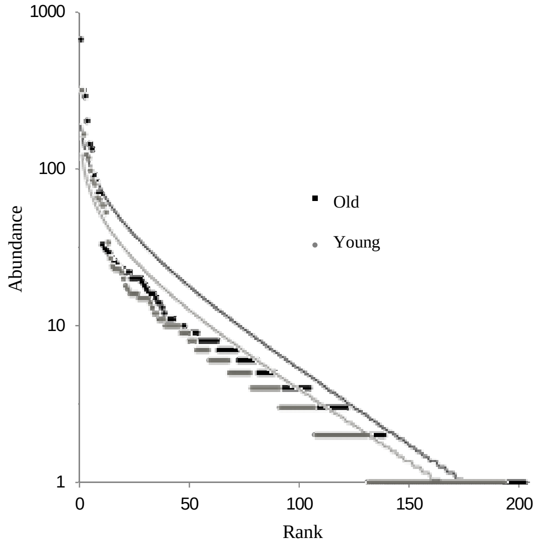

Figure 3. Rank-abundance plot of macromoth communities in old and young forests

We also found some differences in the mean vascular plant abundance of each sample (t-test t = 3.15, p = 0.003); however, this difference was not significant in the case of Lepidoptera abundance (t-test t = 0.97, p = 0.34). We choose the Lepidoptera species that develop on vascular plants as a model group for comparison but found no significant difference in the species number (old forest: 112; young forest: 112) or the mean abundance in each sample (t-test t = 0.28, p = 0.78) either (*Figure 4a-c*).

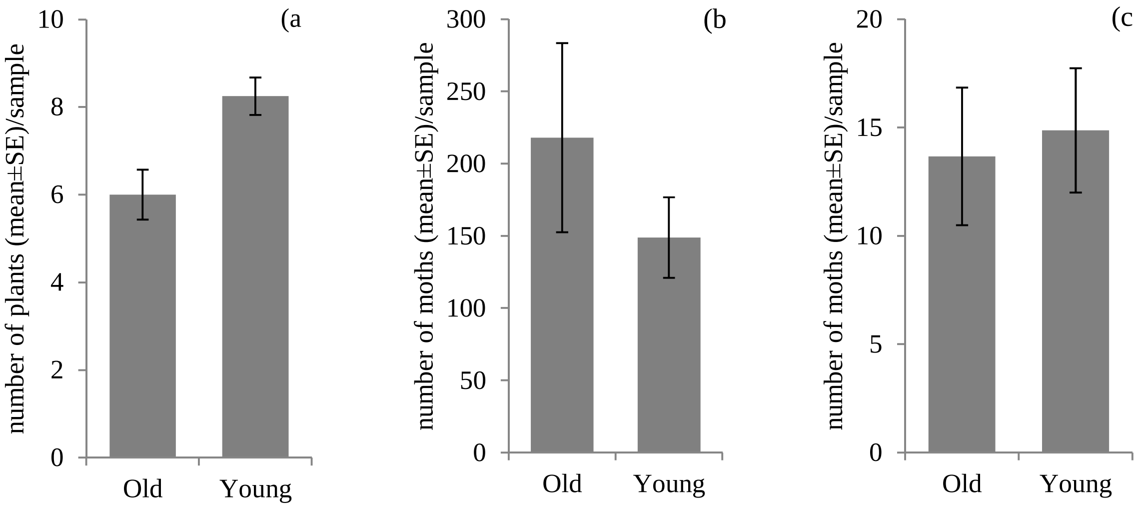

Figure 4a–c. Mean abundances per sample of a) vascular plants, b) nocturnal macrolepidoptera species and c) nocturnal macrolepidoptera species that develop on vascular plants

4 DISCUSSION

Macromoths in the Sopron area are faunistically well studied – approximately 800 species are known (Mészáros – Szabóky 1981, Leskó – Ambrus 1998, Sáfián et al. 2006, Sáfián – Szegedi 2008, Sáfián et al. 2009). Compared to that the number of comparative studies on nocturnal Lepidoptera species in the region is low (Ambrus 1979, Horváth 2013).

The Geometridae family was the most abundant in the investigated forests, although Noctuids are the most diverse group of macromoths in Hungary (Varga 2010). However, number of Geometridae species, which develop on oak species, is higher than in other Lepidoptera families (Csóka – Szabóky 2005). Nevertheless, species richness of Noctuidae was higher both in the old and young forests.

Species richness and abundance of Lepidoptera species were the highest in the old forest stand. This might be associated with the trees' higher foliar biomass product in the old forest (Powers 2001). However, the vascular plant species richness was higher in the young forest. Many species of the ground vegetation survived from the forest clearing. These species will definitely disappear in the growing young forest. Csontos (1996) found similar results in sessile oak - Turkey oak forests regeneration. Nevertheless, there was no difference in the richness of model species (macromoths which develop on vascular plants) between the study sites. Haddad et al. (2001) found a significant positive relationship between insect abundance and plant species richness, however their study was not confined only to the herb layer.

The calculated diversity indices (Shannon, Simpson and Pielou's equitability) were significantly higher in the young forest (both macromoths and vascular plants). The Shannon and Simpson indices show different sensitivities to dominant and rare species and to the equitability. The Shannon diversity formula is calculated using the degree of evenness of the species abundances, whereas the Simpson index is heavily weighted towards the most abundant species in the sample (Peet 1974). It can explain the higher diversity values of macromoths in young forest; however, species richness and abundance of Lepidoptera species were higher in the old forest. Comparison of nocturnal macrolepidoptera species that develop on vascular plants did not show difference between the study sites.

The effect of the vegetation composition on arthropod (especially Lepidoptera) assemblages was proven by many authors (e.g., Axmacher et al. 2009, Taki et al. 2010, Oxbrough et al. 2012). Forest management has an impact on the vegetation, e.g., species richness and species composition (Mark – Lawesson 2000). Nevertheless, forest management also plays an important role in the maintenance of a favourable forest structure for Lepidoptera communities. The forest structure is in under the high influence of the logging method used. Unlogged or selectively cut forest stands are more favourable for diversity and abundance of macromoths (Summerville – Crist 2002, Summerville et al. 2009). Some authors found that the vegetation beneath the forest canopy strongly determines the moth community structure in North-American forested ecosystems (Usher – Keiller 1998, Ober – Hayes 2010). Although the effect of understorey on Lepidoptera species in Hungarian forests is less studied. We supposed that there was an influence of herb layer on macromoths. In contrast, our result did not show an undisputed role of the vascular understory on nocturnal Lepidoptera communities. The explanation of our results may be in connection with the number of study sites and sampling occasion, furthermore with the tight scope of investigated vegetation layer. Henceforward, we suppose a substantial effect of the herb layer on nocturnal Lepidoptera communities, but the complex vegetation structure or other vegetation layers likely play a more significant role in sessile oak forests. The verification of the effect of the different vegetation level and structure on Lepidoptera communities requires further investigations.

Acknowledgements: We express our grateful thanks to Marianna Forgács and Tamás Márton Németh for their help with the field work. The financial backing for the language review was the TÁMOP-4.2.2.B-10/1-2010-0018 project. Further support was provided by the TÁMOP-4.2.2.A-11/1/KONV-2012-0004 project.

REFERENCES

AMBRUS, A. (1979): Újabb adatok a Soproni hegyvidék lepke-faunájához [New data to the Lepidoptera fauna of the Sopron Mountains] Manuscript, Erdészeti és Faipari Egyetem, kézirat, 25 pp + 8 oldal melléklet. (in Hungarian)

AXMACHER, J. C. – BREHM, G. – HEMP, A. – TÜNTE, H. – LYARUU, H. V. M. – MÜLLER-HOHENSTEIN, K. – FIEDLER, K. (2009): Determinants of diversity in afrotropical herbivorous insects (Lepidoptera: Geometridae): plant diversity, vegetation structure or abiotic factors. Journal of Biogeography 36: 337□349.

BENES, J. – CIZEK, O. – DOVALA, J. – KONVIČKA, M. (2006): Intensive game keeping, coppicing and butterflies: The story of Milovicky Wood, Czech Republic. Forest Ecology and Management 237: 353−365.

BÖLÖNI, J. – MOLNÁR, ZS. – BÍRÓ, M. – HORVÁTH, F. (2008): Distribution of the (semi-) natural habitats in Hungary II. Woodlands and scrublands. Acta Botanica 50 (6): 107−148.

CLEARY, D. F. R. – GENNER, M. J. (2006): Diversity patterns of Bornean butterfly assemblages. Biodiversity and Conservation 15: 503−524.

CSÓKA, GY. – SZABÓKY, CS. (2005): Cheklist of Herbivorous Insects of Native and Exotic Oaks in Hungary I (Lepidoptera). Acta Silvatica et Lignaria Hungarica, 1: 59-72.

CSONTOS, P. (1996): Az aljnövényzet változásai cseres-tölgyes erdők regenerációs szukcessziójában [Regeneration succession of sessile oak - Turkey oak forests: Processes in the herb layer] Synbiologica Hungarica 2 (2): 6–122. (in Hungarian)

DÖVÉNYI, Z. (ed.) (2010): Magyarország kistájainak katasztere – Második, átdolgozott és bővített kiadás. MTA Földrajztudományi Kutatóintézet, Budapest, 876 pp. (in Hungarian)

EFRON, B. (1979): Bootstrap Methods: Another Look at the Jackknife. Annals of Statistics 7(1): 1–26.

FISHER, R. A. – CORBET, A. S. – WILLIAMS, C. B. (1943): The relation between the number of species and the number of individuals in a random sample of an animal population. Journal of Animal Ecology 12: 42–58.

HADDAD, N. M. (1999): Corridor and distance effects on interpatch movements: A landscape experiment with butterflies. Ecological Applications 9 (2): 612−622.

HADDAD, N. M. – TILMAN, D. – HAARSTAD, J. – RITCHIE, M. – KNOPS, J. M. H. (2001): Contrasting Effects of Plant Richness and Composition on Insect Communities: A Field Experiment. The American Naturalist 158 (1): 17□35.

HAMMER, Ř. – HARPER, D. A. T. – RYAN, P. D. (2001): PAST – Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica 4(1): 9 pp.

HORVÁTH, B. (2013): Diversity comparison of nocturnal macrolepidoptera communities (Lepidoptera: Macroheterocera) in different forest stands. Natura Somogyiensis 23: 229□238.

JEANNERET, P. H. – SCHÜPBACH, B. – LUKA, H. (2003): Quantifying the impact of landscape and habitat features on biodiversity in cultivated landscapes. Agriculture, Ecosystems & Environment 98: 311–320.

KITCHING, L. R. – ORR, A. G. – THALIB, L. – MITCHELL, H. – HOPKINS, M. S. – GRAHAM, A. W. (2000): Moth assemblages as indicators of environmental quality in remnants of upland Australian rain forest. Journal of Applied Ecology 37: 284−297.

KREBS, C. J. (1989): Ecological Methodology. Harper and Row Publisher, New York, 654 pp.

LESKÓ, K. – AMBRUS, A. (1998): Sopron környékének nagylepkefaunája fénycsapdás gyűjtések alapján. [Macrolepidoptera fauna based on light trappings in the surrounding of Sopron] Erdészeti Kutatások 88: 273–304. (in Hungarian)

Mark, S. – Lawesson, J. E. (2000): Plants as indicators of the conservation value of Danish beech forests. Paper read at Proceedings IAVS Symposium, at Uppsala, Sweden, 26 July–1 August 1998, p. 158–161.

Mészáros, Z. – Szabóky, Cs. (1981): A Fertő-tó nádrontó lepkéi. [Lepidoptera damaging reed in the region of Fertő lake]. Növényvédelem 17 (9):372−375. (in Hungarian)

Mironov, V. (2003): The Geometrid Moth of Europe, Volume 4. Larentiinae II. (Perizomini and Eupithechini). Apollo Books, Stenstrup, Denmark, 464 pp.

Morrison, D. A. – Le Brocque, A. F. – Clarke, P. J. (1995): An assessment of some improved techniques for estimating the abundance (frequency) of sedentary organisms. Vegetation 120:131□145.

New, T. R. (2009): Insect Species Conservation. Cambridge University Press, New York, 256 pp.

Novinszky, L. – Ekk, I. (1996): Normál és UV fénycsapdák Macrolepidoptera anyagának összehasonlítása. [Comparative study of Macrolepidoptera caught in light traps operating with normal and ultra-violet light waves]. Növényvédelem 32 (11): 557−567. (in Hungarian)

Ober, H. K. – Hayes, J. P. (2010): Determinants of nocturnal Lepidopteran diversity and community structure in a conifer-dominated forest. Biodiversity and Conservation 19 (3): 761−774.

Oxbrough, A. – French, V. – Irwin, S. – Kelly, T. C. – Smiddy, P. – O'Halloran, J. (2012): Can mixed species stand enhance arthropod diversity in plantation forest? Forest Ecology and Management 270: 11□18.

Park, M. – An, J-S. – Lee, J. – Lim, J-T. – Choi, S-W. (2009): Diversity of Moths (Insecta: Lepidoptera) on Bogildo Island, Wando-gun, Jeonnam, Korea. Journal of Ecology and Field Biology 32 (2): 129−135.

Pielou, E. C. (1966): The measurement of diversity in different types of biological collection. Journal of Theoretical Biology 13: 131–144.

Powers, R. F. (2001): Assessing Potential Sustainable Wood Yield. In: Evans, J. (ed.): The Forests Handbook. Volume 2. Applying Forest Science For Sustainable Management. Blackwell Science Ltd., London, UK, p. 105–128.

Puskás, J. – Nowinszky, L. (2011): Light-trap catch of Macrolepidoptera species compared the 100 W normal and 125 W BL lamps. e-Acta Naturalia Pannonica 2 (2): 179−192.

Sáfián, Sz. – Ambrus, A. – Horváth, B. (2009): Új fajok Sopron környékének éjjeli nagylepkefaunájában (Lepidoptera: Macroheterocera). [New nocturnal Macrolepidoptera species in the fauna of Sopron and its vicinity (Lepidoptera: Macroheterocera)]. Praenorica Folia Historico-Naturalia 11: 189−201. (in Hungarian)

Sáfián, Sz. – Hadarics, T. – Szegedi, B. – Horváth Á. (2006): Ritka lepkefajok (*Lepidoptera*) előfordulási adatai egy Fertőrákos melletti mészkőbányából. [Occurrence of rare butterfly and moth species (*Lepidoptera*) from a limestone quarry at Fertőrákos]. Szélkiáltó 12: 28–32. (in Hungarian)

Sáfián, Sz. – Szegedi, B. (2008): A behurcolt tölgy-selyemlepke (*Antheraea yamamai* Guérin-Méneville, 1861) (*Saturniidae*: *Lepidoptera*) megjelenése a Soproni-hegyvidéken. [The appearence of Japanese Oak Silkmoth (*Antheraea yamamai Lepidoptera*: *Saturniidae*), an introduced species in the Sopron Mountains (North-West Hungary)]. Szélkiáltó 13: 29. (in Hungarian)

Schmitt, T. (2003): Influence of forest and grassland management on the diversity and conservation of butterflies and burnet moths (Lepidoptera, Papilionoidea, Hesperiidae, Zygaenidae). Animal Biodiversity and Conservation 26 (2): 51−67.

Schowalter, T. D. (2011): Insect Ecology. An Ecosystem Approach. Third Edition. Academic Press, London, 656 pp.

Scoble, M. J. (1992): The Lepidoptera: Form, Function, and Diversity. Oxford University Press, New York, 404 pp.

Shannon, C. E. – Weaver, W. (1949): The mathematical theory of communication. Urbana, Illionis, Univ. Illionis Press, 125 pp.

Simon, T. (ed). (2000): A magyarországi edényes flóra határozója. [Manual of the Vascular Flora of Hungary] Harasztok-virágos növények. Nemzeti Tankönyvkiadó, Budapest, 976 pp.

Simpson, E. H. (1949): Measurement of diversity. Nature 163: 688.

Summerville, K. S. – Crist, T. O. (2002): Effects of timber harvest on forest Lepidoptera: Community, guild, and species responses. Ecological Applications 12 (3): 820−835.

Summerville, K. S. – Crist, T. O. (2003): Determinants of lepidopteran community composition and species diversity in eastern deciduous forests: roles of season, eco-region and patch size. Oikos 100: 134−148.

Summerville, K. S. – Courard-Hauri, D. – Dupont, M. M. (2009): The legacy of timber harvest: Do patterns of species dominance suggest recovery of lepidopteran communities in managed hardwood stands? Forest Ecology and Management 259: 8−13.

Summerville, K. S. – Ritter, L. M. – Crist, T. O. (2004): Forest moth taxa as indicators of lepidopteran richness and habitat disturbance: a preliminary assessment. Biological Conservation 116: 9−18.

Szmorad, F. (2011): A Soproni-hegység erdeinek történeti, növényföldrajzi és cönológiai vizsgálata. [Historical, phytogeographical and coenological investigations in the forests of the Sopron Hills.]. Tilia XVI., 205 pp. + 61 pp. melléklet. (in Hungarian)

Taki, H. – Inoue, T. – Tanaka, H. – Makihara, H. – Sueyoshi, M. – Isono, M. – Okabe, K. (2010): Response of community structure, diversity, and abundance of understory plants and insect assemblages to thinning in plantation. Forest Ecology and Management 259: 607−613.

Tamás, J. (1955): A soproni hegyvidéki erdők történelmi fejlődése, tájleírásai a fafaj, elegyarány és korosztály viszonylatában napjainkig. [Historical development, silvicultural state and description of the forests of the Sopron Mountains] Manuscript, Nyugat-magyarországi Egyetem, Növénytani és Természetvédelmi Intézet, Sopron, 149 pp. (in Hungarian)

Thomas, P. A. – Packham, J. R. (2007): Ecology of Woodlands and Forests. Description, Dynamics and Diversity. Cambridge University Press, Cambridge, United Kingdoom, 528 pp.

Tudor, O. – Dennis, R. L. H. – Greatorex-Daevis, J. N. – Sparks, T. H. (2004): Flower preferences of woodland butterflies in the UK: nectaring specialists are species of conservation concern. Biological Conservation 119 (3): 397–403.

Usher, M. B. – Keiller, S. W. J. (1998): The macrolepidoptera of farm woodlands: determinants of diversity and community structure. Biodiversity and Conservation 7: 725−748.

Varga, Z. (ed.) (2010): Magyarország nagylepkéi. [Macrolepidoptera of Hungary]. Heterocera Press, Budapest, 253 pp.

Wood, D. L. – Storer, A. J. (2003): Forest Habitats. In: Resh, V. H. – Cardé, R. T. (eds.): Encyclopedia of Insects, Academic Press, London, p. 442−454.

1. Appendix: Taxonomic list of collected Lepidoptera species in the sampling sites

Species	Old	Young	Sum
Lasiocampidae			
Poecliocampa populi (Linnaeus, 1758)	1	0	1
Euthrix potatoria (Linnaeus, 1758)	0	1	1
Lasiocampa quercus (Linnaeus, 1758)	1	0	1
Dendrolimus pini (Linnaeus, 1758)	3	0	3
Endromidae			
Endromis versicolora (Linnaeus, 1758)	1	0	1
Shingidae			
Sphinx ligustri (Linneaus, 1758)	13	0	13
Hyloicus pinastri (Linnaeus, 1758)	9	0	9
Laothoe populi (Linneaus, 1758)	1	0	1
Saturniidae			
Aglia tau (Linnaeus, 1758)	3	1	4
Drepanidae			
Watsonalla binaria (Hufnagel, 1767)	1	9	10
Watsonalla cultraria (Fabricius, 1775)	0	1	1
Thyatiridae			
Thyatira batis (Linnaeus, 1758)	5	5	10
Habrosyne pyritoides (Hufnagel, 1766)	10	11	21
Cymatophorima diluta ([Denis et Schiffermüller], 1775)	6	0	6
Achyla flavicornis (Linnaeus, 1758)	1	0	1
Geometridae			
Geometra papilionaria (Linnaeus, 1758)	4	1	5
Comibaena bajularia ([Denis et Schiffermüller], 1775)	9	1	10
Jodis lactearia (Linnaeus, 1758)	3	0	3
Thalera fimbrialis (Scopoli, 1763)	2	8	10
Hemithea aestivaria (Hübner, 1789)	3	0	3
Idaea dimidiata (Hufnagel, 1767)	0	1	1
Idaea trigeminata (Haworth, 1809)	4	1	5
Idaea biselata (Hufnagel, 1767)	8	8	16
Idaea aversata (Linnaeus, 1758)	22	7	29
Idaea degeneraria (Hübner, 1799)	3	4	7
Idaea deversaria (Herrich-Schäffer, 1847)	10	1	11
Scopula nigropunctata (Hufnagel, 1767)	6	2	8
Scopula floslactata (Haworth, 1809)	7	20	27
Rhodostrophia vibicaria (Clerck, 1759)	1	0	1
Timandra comae Schmidt, 1931	1	3	4
Cyclophora annularia (Fabricius, 1775)	9	5	14
Cyclophora quercimontaria (Bastelberger, 1897)	0	1	1
Cyclophora ruficiliaria (Herrich-Schäffer, 1855)	4	7	11
Cyclophora porata (Linnaeus, 1767)	1	6	7
Cyclophora punctaria (Linnaeus, 1758)	20	18	38
Cyclophora linearia (Hübner, 1799)	6	4	10
Xanthorhoe spadicearia ([Denis et Schiffermüller], 1775)	6	3	9
Xanthorhoe ferrugata (Clerck, 1759)	11	3	14
Xanthorhoe quadrifasciata (Clerck, 1759)	1	0	1
Xanthorhoe fluctuata (Linnaeus, 1758)	5	1	6
Catarhoe rubidata ([Denis et Schiffermüller], 1775)	2	0	2
Epirrhoe alternata (Müller, 1764)	1	4	5
Euphyia biangulata (Haworth, 1809)	7	16	23
Euphyia unangulata (Haworth, 1809)	1	0	1
Camptogramma bilineata (Linnaeus, 1758)	0	6	6
Anticlea badiata ([Denis et Schiffermüller], 1775)	1	1	2
Mesoleuca albicillata (Linnaeus, 1758)	9	3	12
Lampropteryx suffumata ([Denis et Schiffermüller], 1775)	23	4	27

Species	Old	Young	Sum
Cosmorhoe ocellata (Linnaeus, 1758)	1	1	2
Nebula salicata ([Denis et Schiffermüller], 1775)	4	1	5
Eulithis populata (Linnaeus, 1758)	2	0	2
Ecliptopera silaceata ([Denis et Schiffermüller], 1775)	1	0	1
Chloroclysta siterata (Hufnagel, 1767)	1	1	2
Chloroclysta miata (Linnaeus, 1758)	1	0	1
Dysstroma truncata (Hufnagel, 1767)	2	1	3
Thera variata ([Denis et Schiffermüller], 1775)	11	0	11
Thera britannica (Turner, 1925)	4	2	6
Electrophaes corylata (Thunberg, 1792)	1	1	2
Colostygia olivata ([Denis et Schiffermüller], 1775)	23	4	27
Colostygia pectinataria (Knoch, 1781)	30	6	36
Horisme tersata ([Denis et Schiffermüller], 1775)	0	1	1
Melanthia procellata ([Denis et Schiffermüller], 1775)	7	2	9
Anticollix sparsata (Treitschke, 1828)	5	1	6
Triphosa dubitata (Linnaeus, 1758)	1	0	1
Philereme transversata (Hufnagel, 1767)	0	1	1
Epirrita dilutata ([Denis et Schiffermüller], 1775)	318	124	442
Perizoma alchemillata (Linnaeus, 1758)	8	10	18
Perizoma albulata ([Denis et Schiffermüller], 1775)	3	0	3
Eupithecia plumbeolata (Haworth, 1809)	2	0	2
Eupithecia abbreviata Stephens, 1831	20	5	25
Eupithecia tantillaria Boisduval, 1840	4	2	6
Eupithecia lariciata (Freyer, 1842)	1	0	1
Eupithecia subfuscata (Haworth, 1809)	1	2	3
Aplocera plagiata (Linnaeus, 1758)	1	0	1
Asthena albulata (Hufnagel, 1767)	33	17	50
Trichopteryx carpinata (Borkhausen, 1794)	0	1	1
Acasis viretata (Hübner, 1799)	0	1	1
Abraxas grossulariata (Linnaeus, 1758)	1	1	2
Lomaspilis marginata (Linnaeus, 1758)	1	1	2
Ligdia adustata ([Denis et Schiffermüller], 1775)	16	34	50
Macaria notata (Linnaeus, 1758)	7	6	13
Macaria alternata ([Denis et Schiffermüller], 1775)	1	6	7
Macaria liturata (Clerck, 1759)	11	0	11
Plagodis pulveraria (Linnaeus, 1758)	19	23	42
Plagodis dolabraria (Linnaeus, 1767)	25	7	32
Hypoxystis pluviaria (Fabricius, 1787)	0	1	1
Apeira syringaria (Linnaeus, 1758)	0	4	4
Ennomos autumnaria (Werneburg, 1859)	0	1	1
Ennomos quercinaria (Hufnagel, 1767)	83	66	149
Selenia dentaria (Fabricius, 1775)	6	5	11
Selenia lunularia (Hübner, 1788)	4	4	8
Selenia tetralunaria (Hufnagel, 1767)	20	15	35
Crocallis elinguaria (Linnaeus, 1758)	4	10	14
Odontopera bidentata (Clerck, 1759)	2	0	2
Colotois pennaria (Linnaeus, 1761)	671	167	838
Angerona prunaria (Linnaeus, 1758)	7	12	19
Lycia hirtaria (Clerck, 1759)	0	1	1
Biston betularia (Linnaeus, 1758)	3	0	3
Agriopis leucophaearia ([Denis et Schiffermüller], 1775)	0	2	2
Agriopis aurantiaria (Hübner, 1799)	14	9	23
Agriopis marginaria (Fabricius, 1776)	0	16	16
Erannis defoliaria (Clerck, 1759)	14	3	17
Peribatodes rhomboidaria ([Denis et Schiffermüller], 1775)	31	118	149
Alcis repandata (Linnaeus, 1758)	8	2	10
Alcis bastelbergeri (Hirschke, 1908)	4	0	4
Hypomecis roboraria ([Denis et Schiffermüller], 1775)	70	4	74

Species	Old	Young	Sum
Hypomecis punctinalis (Scopoli, 1763)	291	53	344
Fagivorina arenaria (Hufnagel, 1767)	20	0	20
Ectropis crepuscularia ([Denis et Schiffermüller], 1775)	91	64	155
Paradarisa consonaria (Hübner, 1799)	7	2	9
Parectropis similaria (Hufnagel, 1767)	4	15	19
Aethalura punctulata ([Denis et Schiffermüller], 1775)	1	2	3
Cabera pusaria (Linnaeus, 1758)	18	7	25
Cabera exanthemata (Scopoli, 1763)	3	10	13
Lomographa bimaculata (Fabricius, 1775)	4	3	7
Lomographa temerata ([Denis et Schiffermüller], 1775)	1	0	1
Campaea margaritata (Linnaeus, 1767)	202	320	522
Notodontidae			
Stauropus fagi (Linnaeus, 1758)	11	1	12
Drymonia dodonea ([Denis et Schiffermüller], 1775)	134	59	193
Drymonia ruficornis (Hufnagel, 1766)	2	6	8
Peridea anceps Goeze, 1781	3	3	6
Pterostoma palpina (Linnaeus, 1758)	0	2	2
Spatalia argentina ([Denis et Schiffermüller], 1775)	6	0	6
Ptilodon capucina (Linnaeus, 1758)	15	1	16
Ptilodon cucullina ([Denis et Schiffermüller], 1775)	3	0	3
Ptilophora plumigera ([Denis et Schiffermüller], 1775)	1	0	1
Phalera bucephala (Linnaeus, 1758)	4	2	6
Clostera pigra (Hufnagel, 1766)	1	0	1
Noctuidae			
Rivula sericealis (Scopoli, 1763)	10	4	14
Trisateles emortualis ([Denis et Schiffermüller], 1775)	4	7	11
Idia calvaria ([Denis et Schiffermüller], 1775)	0	1	1
Paracolax tristalis (Fabricius, 1794)	69	23	92
Herminia tarsipennalis Treitschke, 1835	0	4	4
Herminia tarsicrinalis (Knoch, 1782)	8	13	21
Herminia grisealis ([Denis et Schiffermüller], 1775)	24	23	47
Polypogon tentacularia (Linnaeus, 1758)	3	1	4
Zanclognatha lunalis (Scopoli, 1763)	16	8	24
Hypena proboscidalis (Linnaeus, 1758)	26	80	106
Colobochyla salicalis ([Denis et Schiffermüller], 1775)	1	1	2
Lymantria dispar Linnaeus, 1758	7	1	8
Lymantria monacha Linnaeus, 1758	22	0	22
Calliteara pudibunda (Linnaeus, 1758)	27	2	29
Spilarctia lutea (Hufnagel, 1766)	1	0	1
Diaphora mendica (Clerck, 1759)	0	1	1
Euplagia quadripunctaria (Poda, 1761)	2	3	5
Miltochrista miniata (J. R. Forster, 1771)	4	1	5
Lithosia quadra (Linnaeus, 1758)	0	1	1
Eilema depressa (Esper, [1787])	8	5	13
Eilema lurideola ([Zincken], 1817)	16	10	26
Dysauxes ancilla (Linnaeus, 1767)	1	1	2
Catephia alchymista ([Denis et Schiffermüller], 1775)	0	1	1
Minucia lunaris ([Denis et Schiffermüller], 1775)	1	1	2
Catocala nupta (Linnaeus, 1767)	6	0	6
Catocala promissa ([Denis et Schiffermüller], 1775)	3	3	6
Meganola strigula ([Denis et Schiffermüller], 1775)	7	0	7
Meganola albula ([Denis et Schiffermüller], 1775)	1	0	1
Pseudoips prasinana (Linnaeus, 1758)	0	2	2
Abrostola asclepiadis ([Denis et Schiffermüller], 1775)	1	0	1
Abrostola triplasia (Linnaeus, 1758)	1	1	2
Autographa gamma (Linnaeus, 1758)	1	0	1
Protodeltote pygarga (Hufnagel, 1766)	2	6	8
Deltote deceptoria (Scopoli, 1763)	1	0	1

Species	Old	Young	Sum
Colocasia coryli (Linnaeus, 1758)	144	85	229
Diloba caeruleocephala (Linnaeus, 1758)	1	0	1
Craniophora ligustri ([Denis et Schiffermüller], 1775)	0	2	2
Moma alpium (Osbeck, 1778)	1	3	4
Acronicta (*Jocheaera*) *alni* (Linnaeus, 1767)	0	1	1
Acronicta (*Triaena*) *tridens* ([Denis et Schiffermüller], 1775)	1	0	1
Acronicta (*Viminia*) *rumicis* (Linnaeus, 1758)	3	0	3
Amphipyra (*Amphipyra*) *pyramidea* (Linnaeus, 1758)	3	9	12
Amphipyra (*Amphipyra*) *berbera* Fletcher, 1971	1	0	1
Amphipyra (*Amphipyra*) *livida* ([Denis et Schiffermüller], 1775)	0	1	1
Amphipyra (*Amphipyra*) *tragopoginis* (Clerck, 1759)	0	1	1
Asteroscopus sphinx (Hufnagel, 1766)	8	15	23
Brachionycha nubeculosa (Esper, 1785)	0	1	1
Allophyes oxyacanthae (Linnaeus, 1758)	0	2	2
Helicoverpa armigera (Hübner, 1808)	1	0	1
Caradrina (*Caradrina*) *morpheus* (Hufnagel, 1766)	2	0	2
Caradrina (*Platyperigea*) *kadenii* Freyer, 1836	1	0	1
Caradrina (*Platyperigea*) *aspersa* Rambur, 1834	2	1	3
Hoplodrina octogenaria (Goeze, 1781)	2	0	2
Hoplodrina blanda ([Denis et Schiffermüller], 1775)	1	1	2
Hoplodrina superstes (Ochsenheimer, 1816)	1	1	2
Hoplodrina respersa ([Denis et Schiffermüller], 1775)	1	0	1
Hoplodrina ambigua ([Denis et Schiffermüller], 1775)	5	27	32
Charanyca trigrammica (Hufnagel, 1766)	0	3	3
Rusina ferruginea (Esper, 1785)	12	10	22
Athetis (*Athetis*) *furvula* (Hübner, 1808)	1	0	1
Dypterygia scabriuscula (Linnaeus, 1758)	8	14	22
Trachea atriplicis (Linnaeus, 1758)	9	5	14
Euplexia lucipara (Linnaeus, 1758)	4	15	19
Apamea monoglypha (Hufnagel, 1766)	1	0	1
Apamea syriaca tallosi Kovács et Varga, 1969	0	1	1
Apamea anceps ([Denis et Schiffermüller], 1775)	1	0	1
Loscopia scolopacina (Esper, 1788)	0	1	1
Mesapamea secalis (Linnaeus, 1758)	1	12	13
Mesapamea secalella Remm, 1983	0	3	3
Oligia latruncula ([Denis et Schiffermüller], 1775)	0	1	1
Cosmia (*Calymnia*) *trapezina* (Linnaeus, 1758)	29	98	127
Tiliacea citrago (Linnaeus, 1758)	2	6	8
Tiliacea aurago ([Denis et Schiffermüller], 1775)	1	0	1
Lithophane socia (Hufnagel, 1766)	1	3	4
Lithophane ornitopus (Hufnagel, 1766)	10	10	20
Eupsilia transversa (Hufnagel, 1766)	8	7	15
Conistra (*Conistra*) *vaccinii* (Linnaeus, 1761)	20	15	35
Conistra (*Conistra*) *rubiginosa* (Scopoli, 1763)	0	1	1
Conistra (*Conistra*) *veronicae* (Hübner, 1813)	1	0	1
Conistra (*Dasycampa*) *rubiginea* ([Denis et Schiffermüller], 1775)	0	3	3
Agrochola (*Anchoscelis*) *nitida* ([Denis et Schiffermüller], 1775)	0	1	1
Agrochola (*Anchoscelis*) *litura* (Linnaeus, 1758)	0	1	1
Agrochola (*Anchoscelis*) *helvola* (Linnaeus, 1758)	0	1	1
Agrochola (*Leptologia*) *macilenta* (Hübner, 1809)	5	6	11
Agrochola (*Sunira*) *circellaris* (Hufnagel, 1766)	0	1	1
Agrochola (*Propenistra*) *laevis* (Hübner, 1803)	7	22	29
Xanthia togata (Esper, 1788)	0	4	4
Xanthia icteritia (Hufnagel, 1766)	0	1	1
Xanthia ocellaris (Borkhausen, 1792)	0	1	1
Dichonia aeruginea (Hübner, 1808)	0	1	1
Dichonia aprilina (Linnaeus, 1758)	0	5	5

Species	Old	Young	Sum
Blepharita satura ([Denis et Schiffermüller], 1775)	17	59	76
Mythimna (*Mythimna*) *turca* (Linnaeus, 1761)	2	0	2
Mythimna (*Mythimna*) *pallens* (Linnaeus, 1758)	1	1	2
Mythimna (*Hyphilare*) *albipuncta* ([Denis et Schiffermüller], 1775)	0	4	4
Mythimna (*Hyphilare*) *ferrago* (Fabricius, 1787)	5	16	21
Polia nebulosa (Hufnagel, 1766)	0	1	1
Mamestra brassicae (Linnaeus, 1758)	4	2	6
Lacanobia (*Dianobia*) *thalassina* (Hufnagel, 1766)	5	0	5
Lacanobia (*Diataraxia*) *oleracea* (Linnaeus, 1758)	3	0	3
Hada plebeja (Linnaeus, 1761)	1	1	2
Lasionycta (*Lasionhada*) *proxima* (Hübner, 1809)	1	0	1
Orthosia (*Orthosia*) *incerta* (Hufnagel, 1766)	1	2	3
Orthosia (*Monima*) *cerasi* (Fabricius, 1775)	6	3	9
Orthosia (*Microorthosia*) *cruda* ([Denis et Schiffermüller], 1775)	22	24	46
Orthosia (*Poporthosia*) *populeti* (Fabricius, 1781)	0	2	2
Orthosia (*Cororthosia*) *opima* (Hübner, 1809)	1	0	1
Orthosia (*Semiophora*) *gothica* (Linnaeus, 1758)	3	11	14
Anorthoa munda ([Denis et Schiffermüller], 1775)	2	5	7
Agrotis exclamationis (Linnaeus, 1758)	1	2	3
Agrotis segetum ([Denis et Schiffermüller], 1775)	1	9	10
Agrotis ipsilon (Hufnagel, 1766)	0	4	4
Ochropleura plecta (Linnaeus, 1761)	5	2	7
Diarsia brunnea ([Denis et Schiffermüller], 1775)	1	0	1
Diarsia mendica (Fabricius, 1775)	1	0	1
Noctua pronuba Linnaeus, 1758	8	10	18
Noctua fimbriata (Schreber, 1759)	0	2	2
Noctua interposita (Hübner, 1790)	10	5	15
Noctua comes Hübner, 1813	3	5	8
Noctua janthina ([Denis et Schiffermüller], 1775)	0	2	2
Noctua janthe (Borkhausen, 1792)	0	1	1
Eurois occulta (Linnaeus, 1758)	0	2	2
Xestia (*Xestia*) *baja* ([Denis et Schiffermüller], 1775)	2	3	5
Xestia (*Xestia*) *stigmatica* (Hübner, 1813)	0	1	1
Xestia (*Xestia*) *castanea* (Esper, 1798)	1	0	1
Xestia (*Xestia*) *xanthographa* ([Denis et Schiffermüller], 1775)	0	2	2
Xestia (*Megasema*) *c-nigrum* (Linnaeus, 1758)	6	16	22
Xestia (*Megasema*) *triangulum* (Hufnagel, 1766)	2	0	2
Metagnorisma depuncta (Linnaeus, 1761)	9	11	20